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Extensions of packet communication technology to a hand held personal terminal

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INTRODUCTION

Electronic communications technology has developed historically almost completely within what might be called the circuit switching domain. Not until the last decade has the other basic mode of communication, packet switching, become competitive. Thus, as a technology, packet communication has only begun to be explored. Circuit switching can be defined in the broad sense as the technique of establishing a complete path between two parties for as long as they wish to communicate, whereas packet switching is where the communication is broken up into small messages or packets, attaching to each packet of information its source and destination and sending each of these packets off independently and asynchronously to find its way to the destination. In circuit switching all conflicts and allocations of resources must be made before the circuit can be established thereby permitting the traffic to flow with no conflicts. In packet switching there is no dedication of resources and conflict resolution occurs during the actual flow perhaps resulting in somewhat uneven delays being encountered by the traffic. Clearly, without the speed and capability of modern computers, circuit switching represented a cheaper and more effective way to handle communications. For radio frequency assignment and telephone exchanges the resource allocation decisions could be made infrequently enough that manual techniques were originally sufficient. Also, since voice was the main information being communicated, the traffic statistics were sufficiently compatible with this approach to make it quite economic for the period. Packet switching of a kind, the telegram, persisted throughout this period but due to the high cost of switching and the limited demand for fast message traffic never attracted much attention.

For almost a century circuit switching dominated the communications field and thus dominated the development of communications theory and technology.

Now, within the last decade or less, the advances in digital computers and electronics have, in many cases, reversed the economic balance between circuit and packet communication technology. Perhaps the best proof of this is the economy of the ARPA Network¹⁻³ for country-wide computer to computer communication, but many other examples are beginning to appear such as the University of Hawaii's ALOHA System⁷ utilizing packet radio transmission for console communications and the experiments with digital loops for local distribution. However, most of the experiments with packet communications have been undertaken by computer scientists, and it is not even generally recognized yet in the communications field that a revolution is taking place. Even where the knowledge of one of these experiments has penetrated the communications field, it is generally written off as a possibly useful new twist in communications utilization, and not recognized as a very different technology requiring a whole new body of theory. Throughout the development of the ARPA Network, communication engineers compared it with conventional circuit switched systems but, perhaps unconsciously, used rules of thumb, statistics and experience applicable only to circuit switched systems as a basis for comparison. A century of experience and tradition is not easy to ignore and in fact should not be ignored, only it should be properly classified and segregated as resulting from a different technology.

Packet communication technology is only beginning to be explored but already it is clear that the design of all forms of communications channels and systems should be rethought. As an example of the kind of difference packet communications can make in a perhaps unexpected area, the design of a personal terminal will be explored in some detail. Although such a terminal has never been built, it is most likely completely feasible to build and would provide many unique advantages.

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HAND HELD PERSONAL TERMINAL

Let us start with the goal of providing each individual with a pocket-sized, highly reliable and secure communications device which would permit him to send and receive messages to other individuals or to computers. Leaving the consideration of design alternatives until the end, a device fulfilling these objectives is as follows:

Output

Text or graphics displayed on a 2.8"×1" plasma panel with 80 dots per inch resolution. The screen, divided into 7×10 dot rectangles, using 5×7 characters would hold 8 lines of 32 characters each for a total of 256 characters. Text this size is almost the same size as typewriter print, except that the lines are closer together. The plasma panel has internal storage and is digitally addressed to write or erase a point.

Input

Five capacity or stress sensitive buttons used by the five fingers of one hand simultaneously to indicate one of 31 characters. This five finger keyboard technique was developed by Doug Englebart at SRI⁶ to permit users to type with only one hand while working on a display console. Recently the keyboard has become fairly widely used at SRI due to its great convenience. Training time for a new user is evidently less than a day and speeds of 30 words per minute can be achieved.⁹ Although somewhat slower than a good typist (1/2 speed) the speed is clearly sufficient for a terminal device even at 10 words/minute.

Transmission

Each input character will be transmitted to a central controller station using the random access radio transmission techniques developed at the University of Hawaii.⁷ The 5 bit character is embodied in a 64 bit packet containing:

- 30 bits—Terminal Identification Number
- 8 bits—Character plus alternation bit, or Count
- 2 bits—Type of packet (CHAR, ACK, CNT, ERR, ST ERR)
- 24 bits—Cyclic Sum Check
- 64 bits

All terminals transmit their packets independently and asynchronously on a single frequency and the receiver

at the central controller merely listens for a complete packet which has a correct sum check. If two terminals' transmissions overlap the sum check will be wrong, and the terminals will retransmit when they find they don't receive an acknowledgment. Retransmission time-out intervals are randomized between the terminals to avoid recurrence of the problem. Upon receipt of a good packet, the central station transmits a display-acknowledgment packet back to the terminal on a second frequency. This 144 bit packet contains a 70 bit display raster field and an 8 bit position on the screen. The display raster is a 7×10 dot array for the character sent in and the position includes 3 bits for vertical by 5 bits for horizontal. Current position information for each active user is kept by the central station by user ID in a hash table. Thus, the individual terminal needs no character generation logic, position advancement logic, or any other local verification of the input since the response from the central station both acknowledges the character and displays it in an input text line at the top of the display. If a character display-acknowledgment is somehow lost in transmission the terminal will continue to time-out and retransmit the character. The central station must somehow differentiate this from a new character. This is achieved by an alternation bit^{10,11} in the terminal's packet which is complemented for each new character. On a repeat the bit is the same as previously and the central station just retransmits the same character and position again. When a pre-arranged terminating character is sent the central station examines the message and takes an appropriate action. Considerable flexibility exists here, and operational modes could be established. However, the first message of a sequence should contain a destination as the first item. This might be the ID of another terminal in the same area, it might be the address of a service computer or it might be the ID of another terminal halfway around the world. In the latter two cases, a more global network such as the ARPA Network comes into play. It would be perfectly feasible for a message to another terminal to be sent to a central or area-coded directory computer to locate the particular control station the other terminal was near. Note that the location of neither man was given to the other, only the message and the ID of the sender. (Based on ARPA Network cost estimates and international satellite tariff trends, such a message exchange should cost less than 0.1 cents, independent of distance.)

Reception

At any time when a message destined for a terminal arrives at the central control station, a transmission to

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the terminal may begin, character by character, each in its own 144 bit packet as follows:

- 30 bits—Terminal Identification Number
- 70 bits—7×10 dot pattern, character display
- 8 bits—position of character
- 1 bit —alternation bit
- 1 bit —broadcast mode
- 3 bits—Message Type (Response, initial, normal)
- 8 bits—Characters Left in message
- 24 bits—Cyclic Sum Check
- 144 bits

The terminal must always be checking all transmission to detect those with its ID and a correct sum check. When one occurs which is not a "response" to an input character, a message is being sent. The first character of a message is marked type "initial," and has the count of the remaining characters. Each character is displayed where the central station placed it. Following the "initial" character "normal" characters are checked to make sure the count only decreases by one each time. After the character with count zero, an acknowledgment type packet is sent by the terminal. If this is lost (as it may be due to conflicts) the central control will retransmit the final character over again without complementing the alternation bit until it is acknowledged (or it determines the station is dead). If a count is skipped the terminal sends a CNT ERR message with the count of the character expected. The transmitter then starts over at that count. If a "normal" type character is received before an "initial" type a ST ERR message is sent and the message is restarted. A broadcast bit is included which overrides the ID check for general messages.

Security

Since all transmissions are digital, encryption is possible and would be important no matter what the application, military or civilian. Most private uses such as personal name files, income-expense records, family conversations, etc., would be far more sensitive than current computer console use.

Bandwidth

Personal terminals for occasional use for message exchange, maintaining personal files, querying computer data bases for reference data, etc., would not lead to very heavy use, probably no more than two query-responses per hour. The query we might estimate at 64 characters in length and the response at 256. (Clearly

256 character response could also consist of an 80×224 point graphic display since each character is sent as a full 7×10 raster.) The average bandwidth consumed by each terminal is therefore 2.3 bits/second transmitted and 25.6 bits/second received. The random access technique used for transmission requires the channel bandwidth to be six times the average bandwidth actually utilized in order to resolve all conflicts properly. Thus, the terminal transmission bandwidth consumption is 14 bits/second, still less than the receiver bandwidth needed. Thus, the central control station's transmitter bandwidth is the limiting factor assuming equal bandwidths on both transmitter and receiver. If a 50KHz bandwidth is used for each and modulated at 50K bits/sec, then a total of 2000 terminals can be accommodated. Of course this number depends on the activity factor. At one interaction every two minutes a data rate equal to average time shared console use is obtained and even at this activity 130 terminals can be supported, more than most time-sharing systems can support. With 50 KB channels, the time required to write 256 characters is about one second. Lower bandwidths require increased time, thus, 10KB (5 sec write time) would be the lowest bandwidth reasonable. Even at this bandwidth, with the estimated 2 interactions per hour, 400 terminals could be supported.

COMPARISON

Comparing the effect of the packet technology with the same terminal operating with preassigned Frequency or Time Division Multiplexed channels (ignoring the losses due to TDM sync bits or FDM guard bands) the circuit oriented terminal would require a 40 bit/sec transmit channel and a 4KB receive channel if a 5 sec write time is to be achieved. For 400 terminals with a 5 sec write time, the circuit method would require a total of 1.6 Megabits/sec bandwidth whereas the packet method only requires 20 Kilobits/sec bandwidth. Thus, the circuit technology requires a factor of 80 more bandwidth than the packet technique. Of course, the circuit mode terminals could interact more often within the same bandwidth right up to continual rewrite of the display every five sec, but you would have to massively reshape the user statistics to suit the technology.

Another possibility, to design the terminal so that it performed more effectively in a circuit oriented mode, would be to put character generation logic and position logic in the terminal. This would considerably increase the cost of the terminal, which originally had very little logic except shift registers. The result of adding this logic, however, is to reduce the bandwidth by a factor

of 10 to .16MB or still 8 times the packet technique. The same logic would help reduce the packet size but, in order to maintain the graphic output capability and gross simplicity, it does not seem to pay.

CONCLUSION

As can be seen from the example, packet technology is far superior to circuit technology, even on the simplest radio transmission level, so long as the ratio of peak bandwidth to average bandwidth is large. Most likely, the only feasible way to design a useful and economically attractive personal terminal is through some type of packet communication technology. Otherwise one is restricted to uselessly small numbers of terminals on one channel. This result may also apply to many other important developments, only to be discovered as the technology of packet communication is further developed.

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COMMUNICATIONS TECHNOLOGY

CHANNELS

PACKETS

● END-TO-END CIRCUIT

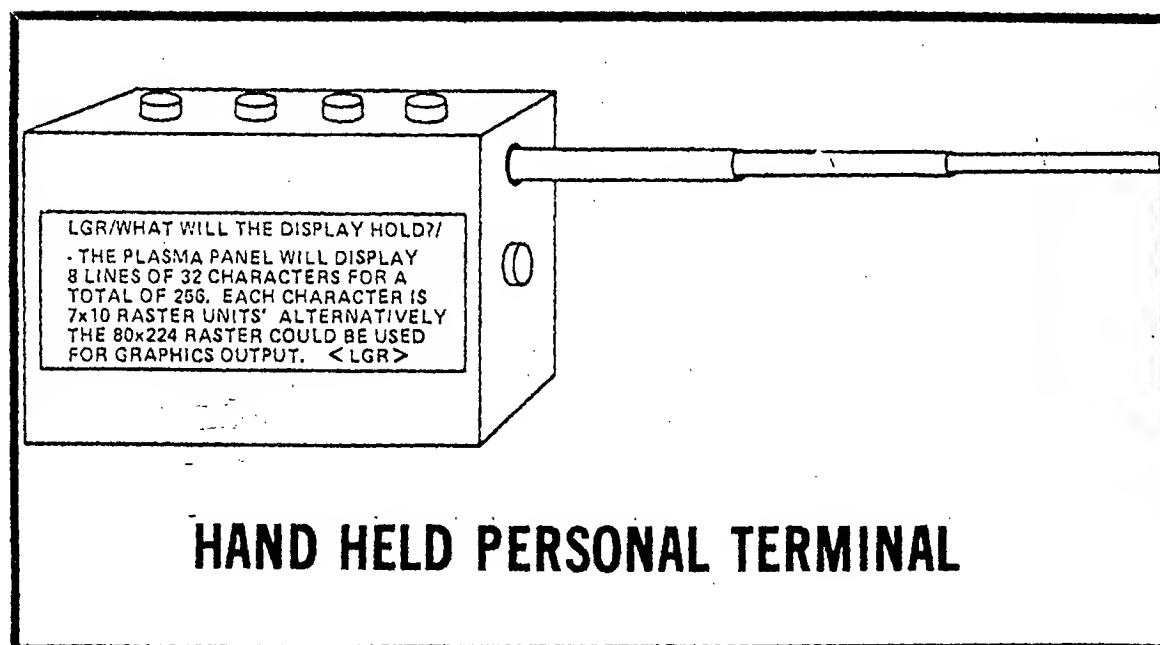
● ADDRESSED MESSAGE

● INFREQUENT DECISIONS

● DYNAMIC RESOURCE ALLOCATION

- TELEPHONE (1876)
- RADIO (1901)
- FACSIMILE (1924)

- TELEGRAPH (1844) AND DESCENDANTS (1960's)
- ARPANET (1969)
- ALOHA NET (1969)



TERMINAL PACKET FORMAT 7/10

ID	*	C	SC
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BITS

30 — TERMINAL IDENTIFICATION

2 — PACKET TYPE

8 — CHARACTER +ALT. BIT
OR
LAST GOOD COUNT

24 — CYCLIC SUM CHECK

64 BITS TOTAL

CENTRAL CONTROL PACKET FORMAT

ID	*	#	XY	7x10 DISPLAY	SC
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BITS

30 — TERMINAL IDENTIFICATION

5 — PACKET TYPE

8 — NO. CHARACTERS LEFT

8 — XY POSITION

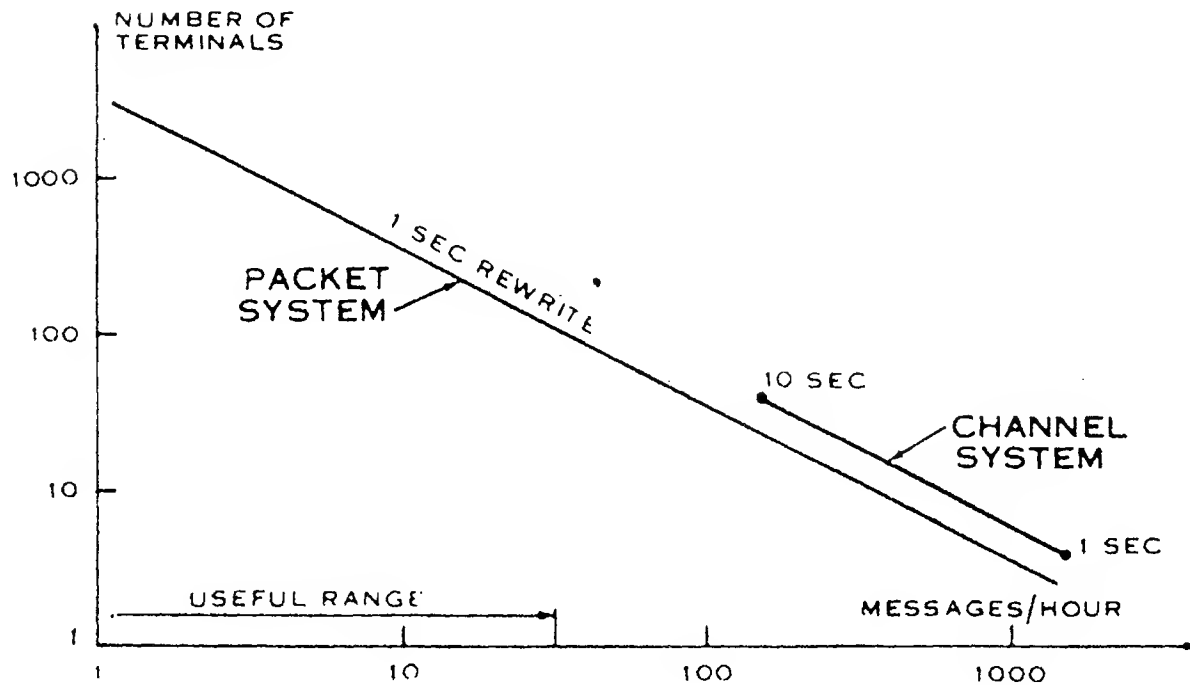
70 — CHAR. DISPLAY DOT MATRIX

24 — CYCLIC SUM CHECK

144 BITS TOTAL

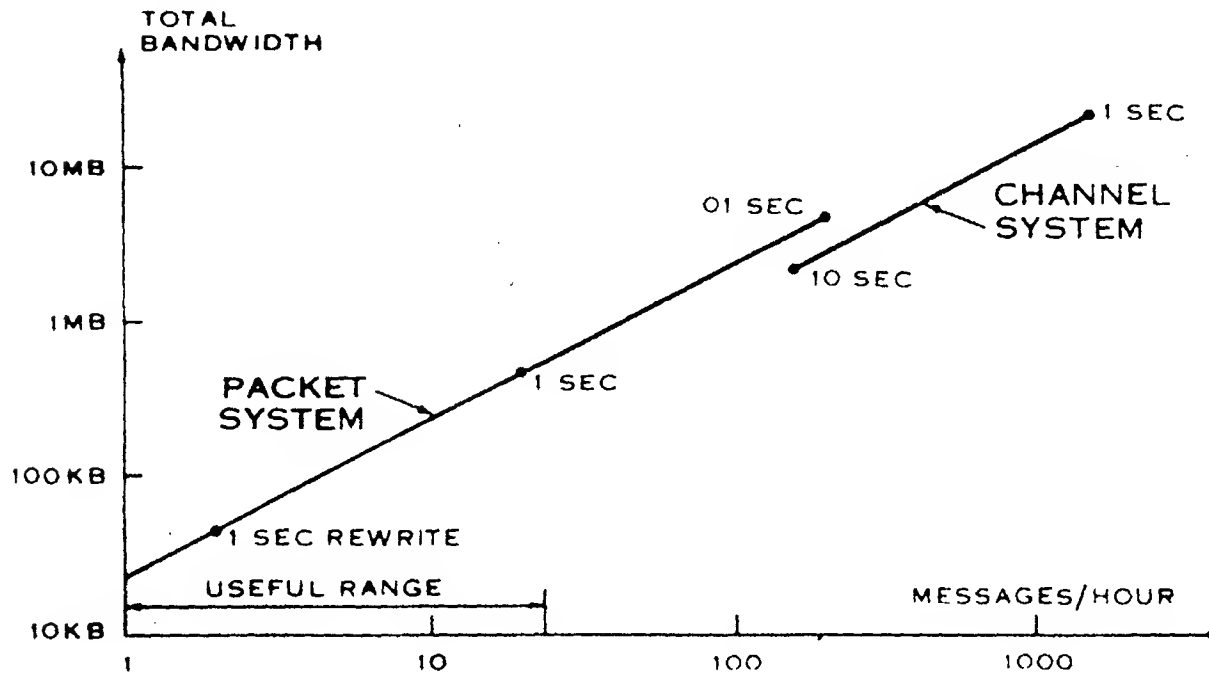
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PERFORMANCE WITH 80 KB BANDWIDTH



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BANDWIDTH REQUIREMENTS FOR 1000 TERMINALS



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PERFORMANCE WITH ≤ 5 SEC DISPLAY REWRITE
FOR A RATE OF 2 MESSAGES/HOUR

